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## **Sea ice—it's more than just frozen water**

By Elizabeth Hunke and Andrew Roberts

The Earth's polar oceans are cold enough that it's possible to walk on sea water turned to ice. About nine million square miles of ice rest float on top of the world's high-altitude seas and oceans. Looking like plates, sheets and mounds of fractured alabaster on a surface of shimmering blue, sea ice is more than a beautiful phenomenon—it influences the Earth's climate, wildlife and people who must contend with it year-round.

Long ago frequented by just a few rugged groups living in the high north, the polar regions are now home to more people than ever, with interests that range across commercial shipping, mining and energy development; recreational fishing, hunting and tourism; scientific research; and military bases and defense operations. Sea ice makes navigation hazardous for shipping. The disappearance of Arctic is changing hunting and fishing practices, as well as the ocean's acoustic properties. Thick ice also complicates the operation and safety of naval submarines.

To support these varied interests, scientists use satellites, aircraft and ships to monitor how far sea ice extends, its thickness in various locations and other topographic characteristics—even its color. Other field research studies the physical and biological processes that influence how ice forms, moves and changes hue.

From the mountains of data provided by this research, scientists develop computer models to forecast the spread and thickness of the ice. The models and real-world monitoring provide insight into how sea ice interacts with the Earth's climate.

In the 1990s, a Los Alamos National Laboratory team developed a software package known as CICE. This powerful software calculates the sea ice's physics, such as how it freezes, melts and moves across the ocean's surface, influenced by external forces such as the ocean's currents and the ever-shifting wind.

Coupling CICE with ocean and atmospheric models, the navy produces predictions of the ice then submits the output data to the National Oceanic and Atmospheric Association and to the National Ice Center, where both organizations incorporate it into their forecasts. Along with a number of other nations, Canada's Environment Department uses CICE to forecast conditions in the Arctic Ocean and its marginal seas. These forecasts include land-fast ice prediction, which they contributed to the CICE codes.

The latest version of CICE, released by the Los Alamos-led CICE Consortium in late 2018, now models land-fast ice, which becomes attached to coastlines and the sea floor. The timing of when sea ice attaches to the shore and when it disintegrates affects the length of shipping, hunting and fishing seasons. Land-fast ice can also block river channels, causing flooding during spring runoffs. Thus, predicting the behavior of land-fast sea ice can directly benefit all kinds of human activity around the polar region.

This new version of CICE also includes a sophisticated description of the sea ice ecosystem, including different types of algae that live in the sea ice and the nutrients that they feed on. The model also simulates dissolved gases that are generated in the sea ice and interact with the atmosphere and the clouds.

How these organisms and chemical processes affect the sea ice itself is important for the polar environment. For example, the ecosystem in sea ice can change its color, making the ice darker or lighter. That hue changes how much energy it reflects from the sun. Pure white sea ice reflects more sunlight, keeping temperatures frigid during winter. Darker ice absorbs more sunlight, warming the waters, melting and thinning the sea ice and curtailing its spread as the oceans warm around the shrinking ice.

Although monitoring sea ice supports commercial, recreational and military activity around the poles, CICE is also helping scientists better understand how sea ice influences climate. When sea ice forms, most of the salt drains into the ocean water below it. Now denser from all that salt, the water below the ice sinks deeper into the ocean and migrates toward the equator while warmer equatorial waters circulate into the polar regions. The relatively fresh ice moves to other locations, and as it warms it suppresses the ocean's circulations by capping the ocean with a lightweight layer of fresher meltwater. Changes in the amount of sea ice can alter the global "conveyor belt" of heat.

With CICE, scientists study how sea ice grows and melts, crumples and moves, and interacts with global climate patterns—a study they can do from a cozy chair in front of a computer screen. Such studies will lead to a better understanding of how sea ice keeps the polar regions cool and helps modulate the global climate.

### **Photos/Captions**



*Elizabeth Hunke and Andrew Roberts are sea ice scientists in the Fluid Dynamics and Solid Mechanics group in the Theoretical Division at Los Alamos National Laboratory. The CICE Consortium is supported through the U.S. Department of Energy's Office of Science, the U.S. Department of Defense, the National Science Foundation, the National Oceanic and Atmospheric Administration and Environment and Climate Change Canada.*



*A seal rests on a slab of sea ice while a ship's crew walk about in the distance.*